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### Chalcogenide IR-Glass Fiber (CIR Fiber)

Chalcogenide Infra Red (CIR) glasses are the best  $As_2S_3$ -based material for fiber optics in the range of 1.5-6 $\mu$ m. CIR fibers transmit IR-radiation in the gap between silica fibers (0.2-2.4 $\mu$ m) and Polycrystalline Infra Red (PIR) fibers (4-18 $\mu$ m). CIR fiber is drawn in core/clad structure with double polymer coating and characterized by a low optical losses and high flexibility.

The innovative glass purification process provides the attenuation spectra free from OH absorption band at 3 $\mu$ m and thus it enables CIR fiber to be used for Er:YAG laser power delivery.

#### Features

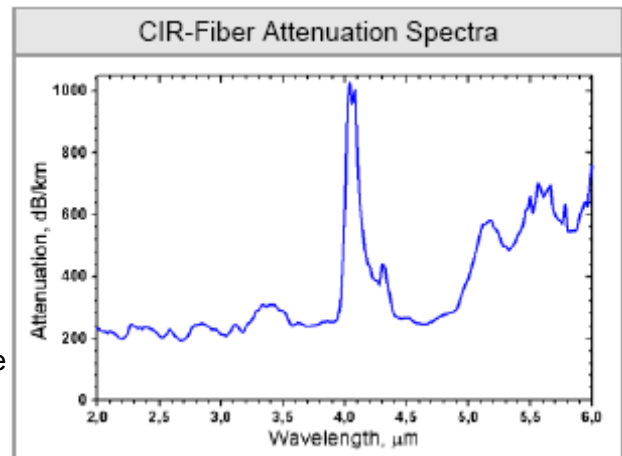
- high transmittance from 1.5 $\mu$ m up to 6 $\mu$ m
- suitable for Er:YAG - laser power delivery
- optical losses 0.2 dB/m at 2-4 $\mu$ m
- double polymer coating for high flexibility
- durable cables with SMA-connectors

#### Applications

- Flexible delivery for Er:YAG - laser
- flexible IR-imaging systems
- remote non-contact pyrometry in the 200-600K range
- fiber probes for remote process IR - spectroscopy

#### Fiber specification

Transmission Range	1.5 - 6 $\mu$ m
Core/Clad Structure	As <sub>2</sub> S <sub>3</sub> /As-S
Core/Clad Diameter	200-500/300-600 $\mu$ m
Core Refractive Index	2.4
Effective NA	0.28
Protective Coating	Double Polymer Jacket
Ambient Temperature Range	270 - 370 K



#### CIR Infrared Optical Fiber Standard Cables

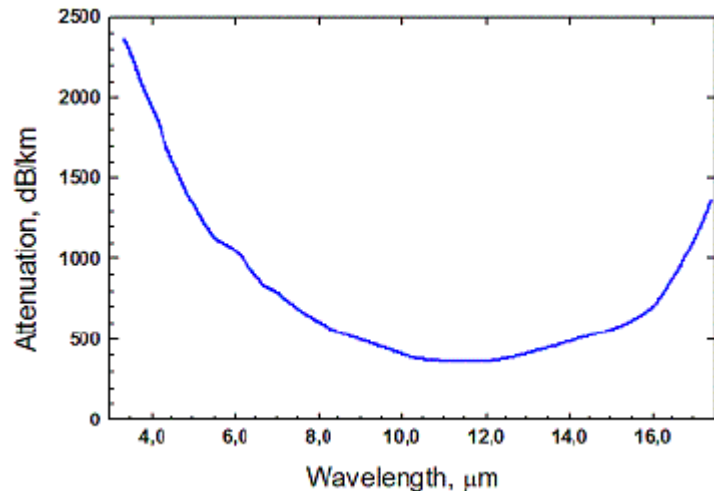
Chalcogenide Infra Red (CIR) (1.5 - 6 $\mu$ m) fiber is drawn in core/clad structure with double polymer coating and characterized by a low optical losses and high flexibility. Delivery is from stock or within few weeks ARO. All standard cables include PEEK-polymer protective jacket and SMA termination.

## Polycrystalline Infra Red Fibers (PIR – Fibers)

The development of specialty fibers for the Mid-Infrared region has resulted in a unique product - Core / Clad Polycrystalline Infra-Red (PIR-) fibers. The PIR-fibers are non-toxic, very flexible, transparent across a broad spectral region 4 -18 $\mu$ m and capable of operating over the wide temperature range of 4K up to 420K. They are manufactured in a core/clad structure of superior quality from pure AgCl: AgBr solid solution crystals using an innovative vacuum extrusion method. They possess by no aging effect compared to an alternative bare core fiber. The range of PIR-fiber cables are available with a durable PEEK polymer jacket and terminations using either an SMA - type connector with a Ti or polymer ferrule or special one, manufactured on customer request. A wide variety of different optical coupling units can also be designed & fabricated for specialized customer requirements.

### Fiber Features:

- high transmittance from 4 $\mu$ m up to 18 $\mu$ m
- high flexibility and no toxicity
- suitable for CO<sub>2</sub> - laser power delivery up to 50W
- low Attenuation at 10.6 $\mu$ m (0.1-0.5 dB/m)
- fiber diameters from 0.3 to 1.0mm
- fiber lengths up to 20m (for 0.5mm diameter)
- no aging effect



### Standard Fiber Specification:

Standard Fiber Core/Clad Diameters Other fiber diameters in 0.3-1.5mm range are also available (request on special fabrication)	240/300, 400/500, 630/700, 900/1000 $\mu$ m
Transmission range	4-18 $\mu$ m
Attenuation at 10.6 $\mu$ m	0.1-0.5 dB/m
Refractive index	2.15
Standard Effective NA	0.25
Laser Damage Threshold for CW CO <sub>2</sub> -laser	>12 kW/cm <sup>2</sup>
Melting point	415°C
Tensile strength	>100 MPa
Minimum Bending Radius (fixed)	10x[Fiber Diameter]
Minimum Elastic Bending Radius	100x[Fiber Diameter]

PIR-fibers are protected by a loose PEEK-jacket (PolyEtherEtherKetone) to provide stiff, flexible and hermetic protection against mechanical, photoinduced and chemical damage over a wide temperature range up to 250°C.

### Standard Cable termination with a special Ti-ferrule SMA-connector:

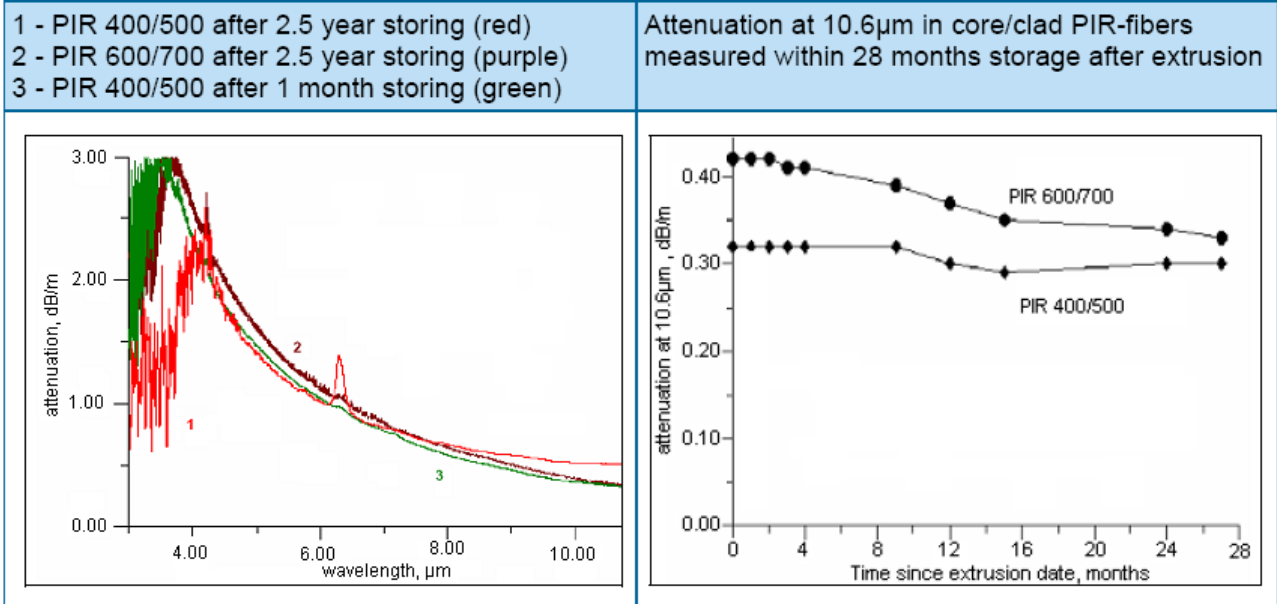
- for low power (spectroscopy & radiometry) applications;
- for high laser power delivery - free standing fiber end ;
- standard cable length - 1m & 2m.

### PIR-fiber end-surface treatment:

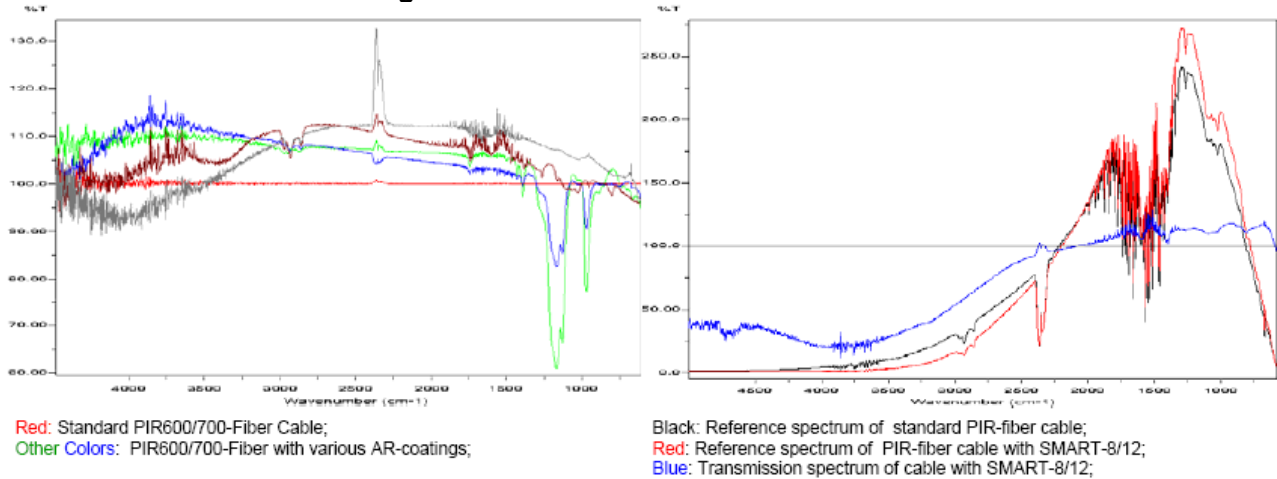
- Cutting low cost, high performance - standard;
- Polishing for special application, including AR-coating - on request;
- SMART for reduced reflection of high CO<sub>2</sub>-laser intensity - on request.

### Options

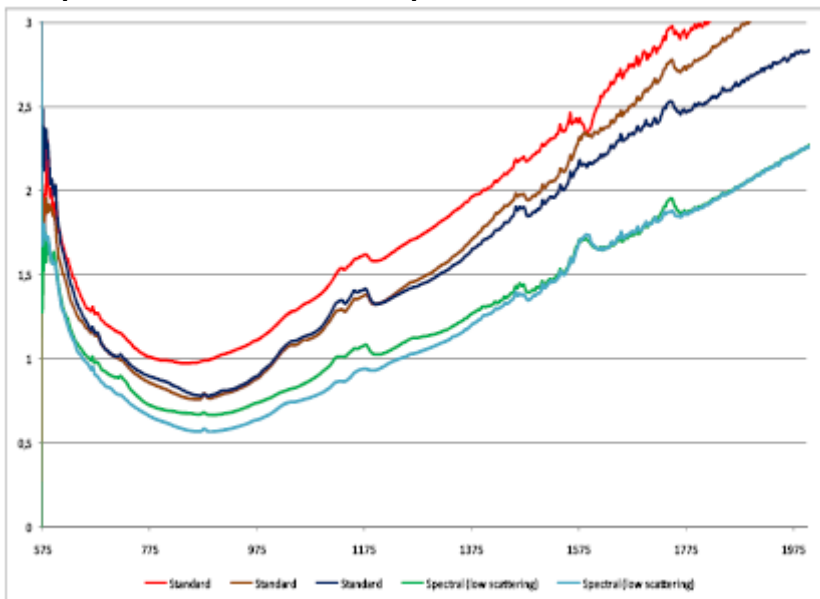
- accessory kits for remote spectroscopy with FTIR, QCL and TDL-spectrometers;
- pig-tailing of IR-detectors: TE- & LN-cooled MCT, PbSe, thermopiles, etc.



**Diverse Methods of AR-coating and SMART-treatment**



**Comparison of Standard and Spectral PIR-fibers**

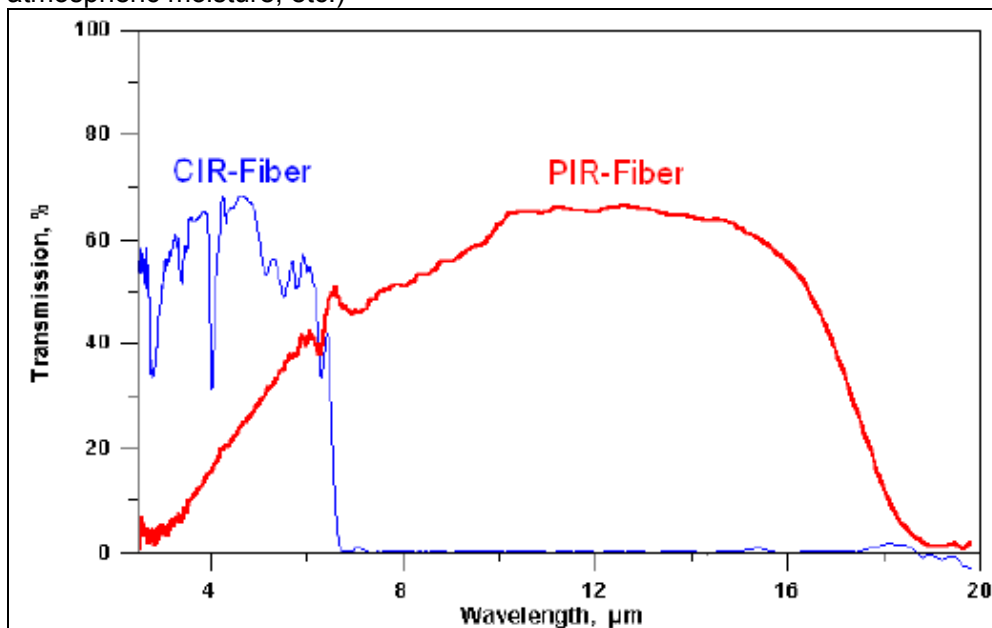


**Applications**

- Flexible delivery system for CO and CO<sub>2</sub> laser;
- Flexible IR-imaging systems;
- Remote non-contact pyrometry in the 100-600K range;
- Fiber probes for remote in-line, in-vivo and process IR - spectroscopy.

## Comparison of CIR- and PIR-Fibers

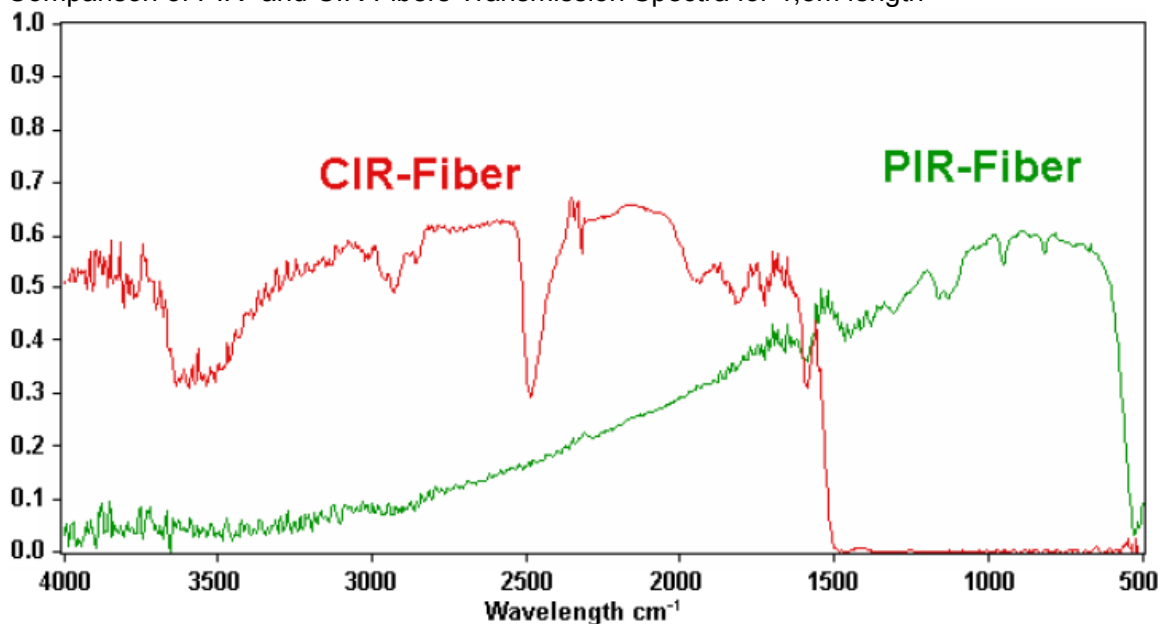
Typical transmission spectra of 1.5m long PIR-900/1000 fiber (red) versus CIR-750/850 fiber (blue) (includes reflection & coupling losses at fiber ends without AR coating and some absorption bands of atmospheric moisture, etc.)



### Typical specification of CIR- and PIR-fibers

No.	Parameter	CIR-Fiber	PIR-Fiber
1.	Transmission range	1.5 to 6μm or 1600- 6500cm <sup>-1</sup>	3 to 18μm or 550 - 3300cm <sup>-1</sup>
2.	Core/Clad structure materials	Chalcogenide As-S glasses	AgCl:AgBr solid solution crystals
3.	Specific Features	Toxic & Fragile, Non-hygroscopic	Non-toxic, Non-hygroscopic, very flexible, slightly UV-sensitive
4.	Core/Clad diameter	200-500/300-600μm	400/500, 630/700, 700x700, 900/1000μm
5.	Core refractive index	2,4	2,2
6.	Effective NA	0,28	0,25
7.	Optical losses	Minimum of 0,2dB/m at wavelengths 2-4μm	Minimum of 0,2-0,3dB/m at wavelengths 10-12μm
8.	Operation temperature	From 270 to 370K	From 4 to 420K
9.	Max length of cable	Up to 50-100 meters	Up to 20-40 meters

### Comparison of PIR- and CIR-Fibers Transmission Spectra for 1,5m length



## STHPFC-9— Power Fiber Cables for Diode Lasers

Our Power Fiber Cables (PFC) with PC-SMA905 connector exploit the air-gap-ferrule design, where the fiber prolongs into free space securing an epoxy-free area, where thermal energy can be safely dissipated without burning the surrounding material, making them ideal for high-power applications.

A heat-sink is attached to the rear of the connector, which conducts extraneous heat away from the fiber, further reducing the possibility of breakdown.

Each cable assembly goes through the tight Quality Control with several examinations during the fabrication process, including extensive inspection of fiber tip quality by FiberCheck® technique, leading, as a result, to a special product.

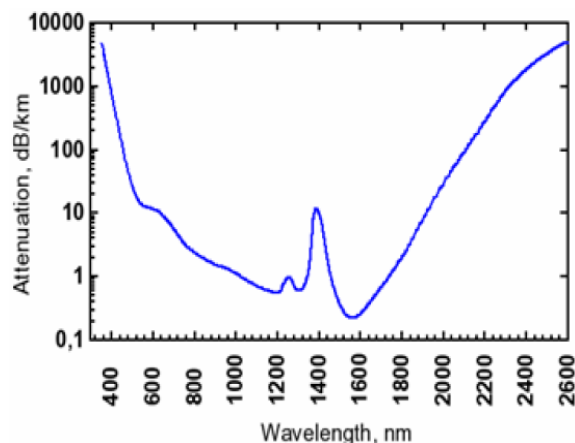


### VIS-NIR—Low OH Fiber

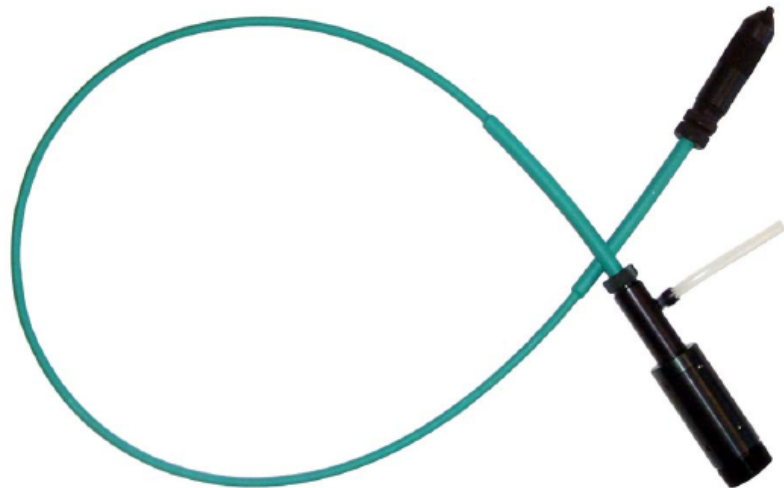
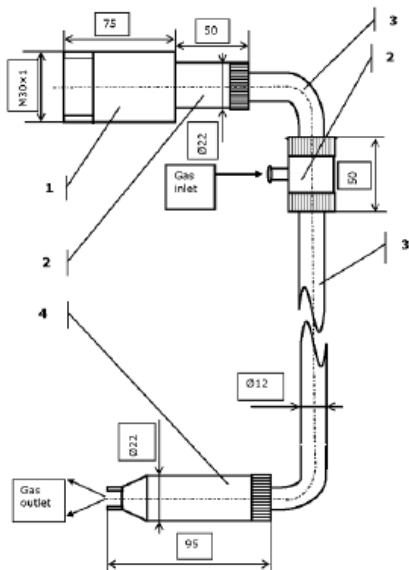
- Operating Wavelength Range: 350-2500 nm
- Damage Threshold: >5J/mm<sup>2</sup> (1ms pulse at 1060 nm, & > 1.3 kJ/mm<sup>2</sup> CW at 1060 nm)
- PC-SMA 905 connector
- Anodized aluminum heat sink
- Air-Gap-Ferrule Epoxy Free

### STHPFC-9 General Specifications

Core	Pure fused silica (low OH-)
Core diameter (µm)	9
Cladding	Fluorine doped fused silica
Cladding diameter (µm)	135
Coating	Polyimide coating (-190°C to 385: C)
Protective tube	Silicon coated Stainless Steel
Numerical aperture	0.22
Fibre connector	PC-SMA905
Length	3 m
Max. laser power (W)	1 W
Short term bending radius (cm)	3.6
Long term bending radius (cm)	14.4



## PIR-fiber delivery set for CO2 laser



Application	A medical laser delivery system is destined for transmission energy of laser to a surgical site of a patient.	
	Used in: Stomatology, Urology, Proctology	
Includes	1) Adjustable coupler to laser head	
	2) Hermetic unit	
	3) PIR-fiber cable	
	4) Focusing handpiece	
Common features	Total transmission (1.5 m length)	>70%
	Maximum input power	50 W CW
	Minimal bending radius	10 cm
Focusing handpiece	Focusing handpiece diameter	max 22 mm
	Focusing handpiece length	max 100 mm
	Focal spot size	0.65-0.9 mm
	Operating distance away from lens	20 mm
	Operating distance away from exit	3-4 mm
PIR-Fiber cable	According to PIR-fiber specifications, in PEEK tubing and outer jacket, carrying cooling gas, Ti-SMA-connectors	
Coupler to laser head	Maximal laser beam diameter	8 mm
	Diameter	30 mm
	Length (with hermetic unit)	140 mm
	Connecting dimensions	Screw M30x1
Hermetic unit	Nipple dia	6 mm
	Cooling gas pressure	0.1-0.15 atm

## Refocusing & Collimating Fiber/Lens Objectives

### Features

- Compatible with SMA-terminated fiber cables
- NA=0.35, Pupil diameter 14 mm
- Refocusing or collimating design

### Applications

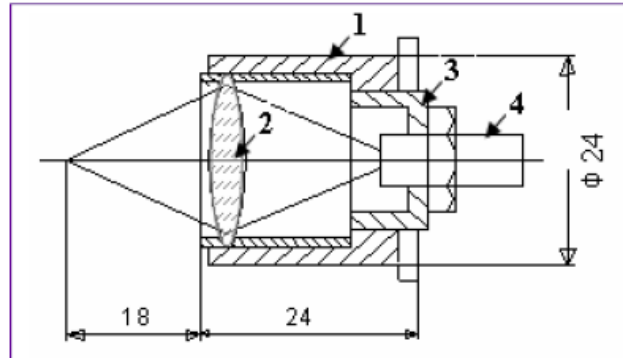
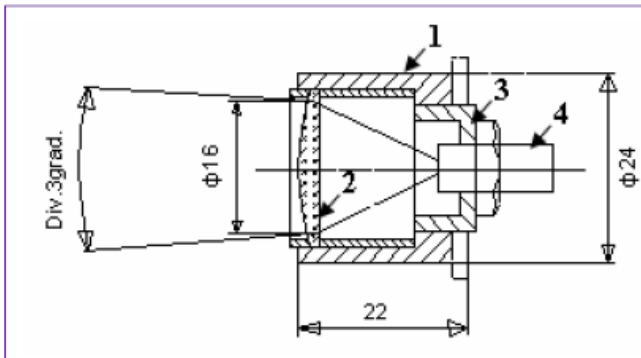
- Focusing of collimated beam into fiber
- Collimation of output beam from fiber
- Fiber end imagnation to detector / emitter element

### Technical parameters

- Z-translation stage adjustable in  $\pm 5$  mm range Lens parameters
- ZnSe or Ge - on request
- $\varnothing 15$  mm;  $f = 20$  mm or  $10$  mm - on request
- AR - coating for  $3-5.5\mu\text{m}$  or  $8-12\mu\text{m}$  - on request



### Drawings



- 1-Case
- 2- Lens
- 3- Z-translation stage
- 4- SMA-Adaptor

## High Power Silica Fiber Cables

We are one of leading suppliers of high-power silica fiber cables for industrial, medical and scientific applications. We offer Fiber Cables in a variety of fiber diameters, protective tubings and connectors, as shown below. Our High Power Fiber Cables exploit the air-gap-ferrule design, where the fiber prolongs into free space securing an epoxy-free area where thermal energy can be safely dissipated without burning the surrounding material, making them ideal for high-power applications. The connector ferrules, fabricated from stainless steel and copper, are used as a heat sink, pulling the heat quickly away from the fiber.



### Applications:

- Laser Welding
- Laser Cutting
- Medical Laser Delivery
- Laser Target & Rangefinder
- Laser Spectroscopy
- Avionics
- Defense and Military
- Life science
- Airspace



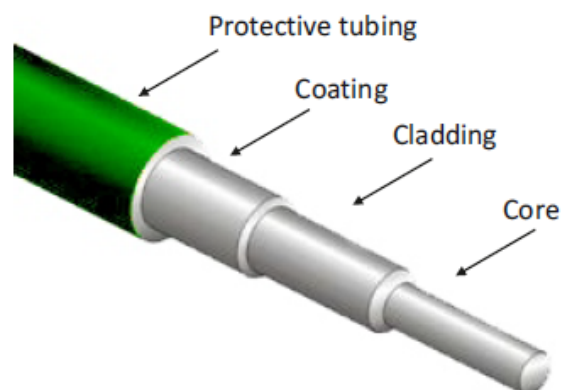
### Features

- Highest purity of silica fibers (UV,VIS,NIR)
- Metal coated fibers (high temperature applications)
- AR-coating of fiber end face
- Air-Gap-Ferrule epoxy free
- Custom design HP-SMA (High Power) connector - (fiber tip incorporate a pure fused silica capillary)
- Polished or Cleaved end face
- ISO 9001:2008 certified production
- Comprehensive quality control system



### Anatomy of an Assembly

For assembling Optical Cables the multimode fibers with core from pure fused silica and the cladding from fluoride doped silica are used. A buffer material is then applied. A buffer coats the core and cladding, strengthens the fiber. In most assemblies polyimide is used as the buffer; other assemblies use aluminum or acrylate. Then protective tubing is applied over the core, cladding and buffer to protect the fiber and provide strain relief. The standard jacketing is stainless steel silicone monocoil. Precision optical Connectors terminate the cable and are precisely aligned to ensure concentricity of the fiber. Finally, end caps protect the fiber tips against scratches and contaminants.





## Choosing the Right Fiber Cable for Laser Power Delivery

The most critical issue in building Laser Power Delivery System is choosing the right Optical Fiber Cable. Three main parameters are important to make right selection:

### 1. Fiber type & core diameter 2. Coating and protective tube 3. Connector Choosing the Fiber

One important consideration in ordering an optical fiber assembly is which fiber type you should specify for your application. Typically, the wavelength range needed for your application should match the wavelength range of the fiber type.

**Low OH<sup>-</sup> and High OH<sup>-</sup> Optical Fiber:** The optical attenuation characteristics are quite different for high OH<sup>-</sup> and low OH<sup>-</sup> optical fiber core material. For UV-VIS spectral range ( $\lambda = 0,18 - 1,2 \mu\text{m}$ ) Silica-Silica fibers with High OH<sup>-</sup> content should be used and for VIS-NIR range ( $\lambda = 0,35 - 2,5 \mu\text{m}$ ) – Silica-Silica fibers with Low OH<sup>-</sup> group concentration are more convenient.

The next significant parameter is the fiber core diameter. Smaller fiber cores are preferred in order to get the best beam quality and high flexibility. However optical fiber cables have several restrictions in their power transmitting capabilities, and there are important limitations to selecting the appropriate (smallest) fiber size. The laser itself imposes constraints on the smallest fiber that can be used.







#### Maximum CW Power for Each Fiber Diameter

Core Dia., $\mu\text{m}$	Square, ( $\text{mm}^2$ )	CW Power, (W)
50	0.0020	10
100	0.0079	25
200	0.0314	50
400	0.1256	100
600	0.2826	300
800	0.5024	600
1000	0.7850	800

#### Fiber Specifications

Core	Pure silica
Cladding	Fluorine doped fused silica
Coating	Acrylate coating (-40°C to 85°C). Silicone resin coating (-40°C to 180°C) Polyimide coating (-190°C to 385°C)

#### Protective tubing

Tube Type	PVC Monocoil	PEEK	PVC over Brass Tube	Silicone Monocoil	Stainless-steel BX	Stainless-steel fully interlocked
						
Temperature Limits	70 °C	260 °C	100 °C	250 °C	250 °C	250 °C
Chemical Resistance	Poor	Excellent	Good	Good	Good	Good
Steam Sterilizable	No	Yes	No	Yes	Yes	Yes
Mechanical Tolerance	Good	Good	Good	Good	Poor	Excellent

## Choosing Connectors

Selecting the right connector for your needs can be complicated by the many choices available today. Choosing the best fiber optic connector for any installation will have an impact on how efficient and cost-effective the job is completed.






In today's Laser Power Fiber Delivery System, there are various optical fiber connector types: SMA, ST, FC/PC, FC/APC, DL80, D-200 connectors, cap-customized. Bespoke Mitsubishi connector design may include ferrule protection by sapphire ring to prevent metal evaporation by intensive laser beam.

High power connectors feature an air-gap design, where the fiber extends into free space by 1.1mm to 1.5mm, providing an epoxy-free region where thermal energy can be safely dissipated without burning the surrounding material. This is the key mechanism for failure in standard connectors.

In addition we utilize a number of unique methods of polishing fiber tip or fusing a glass end cap to the end of the fiber (cap connector) to maximize power handling.

High power connectors compatible with SMA 905 and FC receptacles are offered.

Finally, each cable assembly goes through the tight Quality Control with several examinations during the fabrication process, including extensive inspection of fiber tip quality by Fiber Check technique. Data will help alleviate the confusion by reviewing the basic considerations prior to deciding on the best connector for an installation.

<p><b>SMA</b> FC/PC; FC/APC ST</p> <p>Max Power 20 W</p>	
<p><b>SMA— free end</b></p> <p>Max Power 40W</p>	
<p><b>HPC</b> High Power Connector</p> <p>up to 100 W</p>	
<p><b>SHPC</b> (Super High Power),</p> <p>up to 200 W</p>	
<p><b>Cap Connector</b></p> <p>&gt;200 W CW and pulsed Lasers</p>	



## Ordering Information

<b>Connector Type</b> SMA; FC/PC; FC/APC; ST SMA- free end HPC SHPC Cap	<input type="text"/>
<b>Fiber Core Diameter</b> 100µm 200µm 400µm 600µm 800µm 1000µm 1500µm	<input type="text"/>
<b>Length, m</b>	<input type="text"/>
<b>Numerical Aperture</b> 0.22 0.12	<input type="text"/>
<b>Operating Wavelength</b> UV NIR	<input type="text"/>
<b>Protective Tubing</b>	<input type="text"/>

## LASER-INDUCED DAMAGE IN FIBERS

High intensity of a laser beam can destroy a fiber. Theoretically it is defined by damage threshold of a fiber. Unfortunately in practice fibers and cables are often distracted because of improper handling. The most general cause of such a destruction is an absorption of laser beam energy by some object connected with the fiber. It can be, for example, dust particles, which set on an endface of a fiber from air, or particles of smoke' from the object, burned by the laser beam. So each endface of a fiber must be watched before work and cleaned, if there are some alien particles or stains on it. The output endface must be flowed by clean air, if there is a possibility to stain it. When not used the endface must be protected by a cover.

Input connector may be heated because of improper coupling. The diameter of a laser beam, focused by a coupling objective must be less than the diameter of a fiber core. If there are wings in energy distribution, because of high order modes or aberrations of the objective, they must be cut off by a diaphragm. Aperture of a focused beam must be less than aperture of a fiber also.

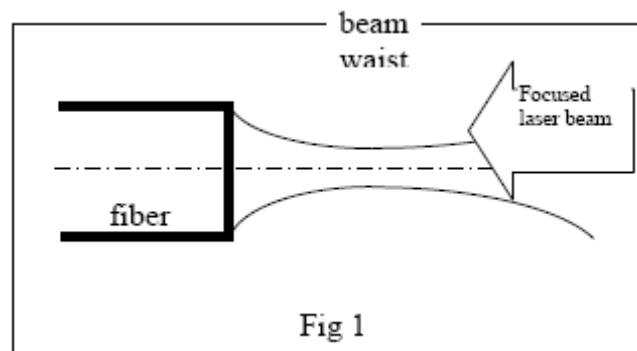
Laser beam, formed by coupling objective, must be carefully micropositioned. Linear displacement of input beam leads to heating of construction details and also to destruction of a fiber.

Another cause of fiber damage is a local energy concentration in fiber material. It may occur if one puts an endface of a fiber before the waist of a focused laser beam.

Proper position of the endface is behind the waist (Fig.1). Angle displacement of a beam leads to its focusing by a reflecting fiber core boundary and to local energy concentration that destroys a fiber.

Micropositioning, of the input beam must be started from low level of laser beam energy and be carried out very carefully. Sometimes the damage occurs in the place of a hidden defect (alien particle, excessive bending, or some other defect of structure).

In the case of continuous radiation of CO<sub>2</sub> laser and PIR-fiber, in spite of nearly the same surface absorption for both ends, melting -starts from the output end as a rule. It is caused by a superposition of direct and reflected speckle patterns of light waves near the output end. Random addition of these patterns leads to some local maximums, and melting begins at the points with the highest local intensity. For IR fibers the threshold intensity averaged over the whole cross-section is about 7-10 kW/cm<sup>2</sup>. This intensity can be increased by cooling of the end surface by a flow of dry gas.



Investigations on the transmission of pulsed radiation of TEA CO<sub>2</sub> laser through polycrystalline fibers have shown that the damage usually occurs in the initial part of a fiber at distances from several millimeters up to several centimeters from the input end. Fiber damage threshold induced by a pulse is significantly lower than in initial crystals. This effect can be associated with the focusing of input radiation by the cylindrical side the surface of the fiber. Estimated values of the threshold in fibers with regard to the additional focusing correspond to the bulk threshold at initial crystals.

**Do not hesitate to connect with us for technical consultation!**